IWP Comparison in Deep Convective Systems among CERES-MODIS, GOES, and Radar Retrievals

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Publications

- Wang, J., X. Dong, and B. Xi, 2015. Investigation of Ice Cloud Microphysical Properties of DCSs using Aircraft in situ Measurements during MC3E over the ARM SGP Site, JGR, 120, 3533-3552, 10.1002/2014JD022795.
- Tian, J., X. Dong, B. Xi, J. Wang, and C. R. Homeyer, 2015. Retrievals of Ice Cloud Microphysical Properties of Deep Convective Systems using Radar Measurements, submitted to JGR.
- Qiu, S., X. Dong, B. Xi, and J.-L. F. Li ,2015. Characterizing Arctic mixed-phase cloud structure and its relationship with humidity and temperature inversion using ARM NSA Observations, JGR, JGR. 120, doi:10.1002/2014JD023022.
- Wu, P., X. Dong, and B. Xi, 2015: MBL drizzle properties and their impact on cloud microphysical property retrievals. Atmos. Meas. Tech., 8, 1-17, 2015.
- Dong, X., B. Xi, S. Qiu, P, Minnis, S. Sun-Mack, S. Kato, and F. Rose, 2015: A Radiation Closure Study of Arctic Cloud Microphysical Properties using the collocated satellite-surface data and Fu-Liou Radiative Transfer Model. In preparation for JGR.

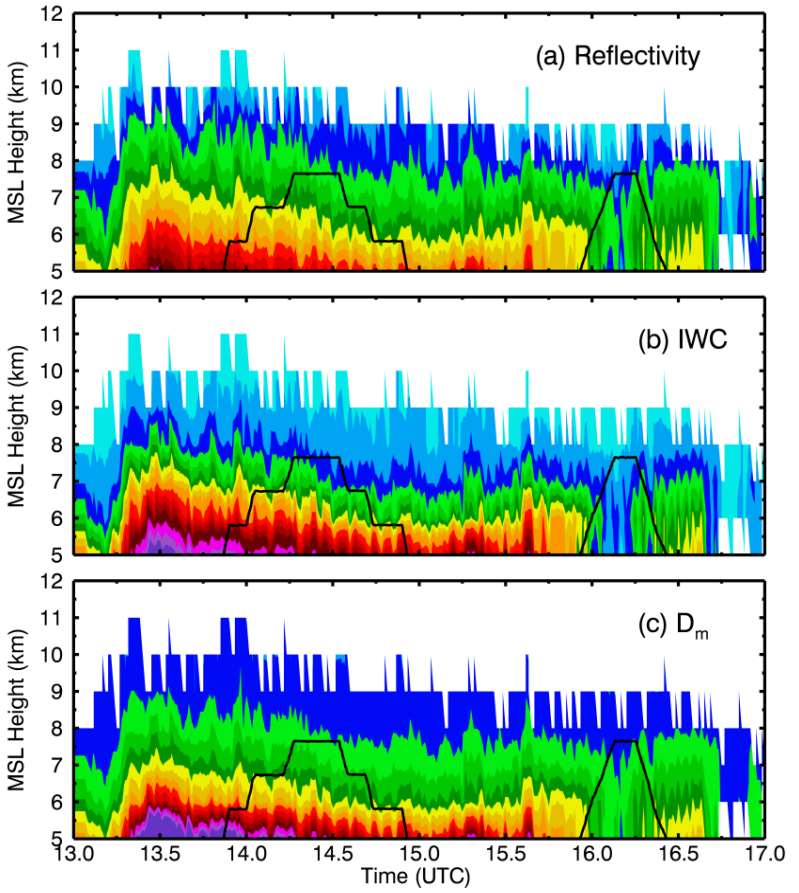
Motivation and Goals

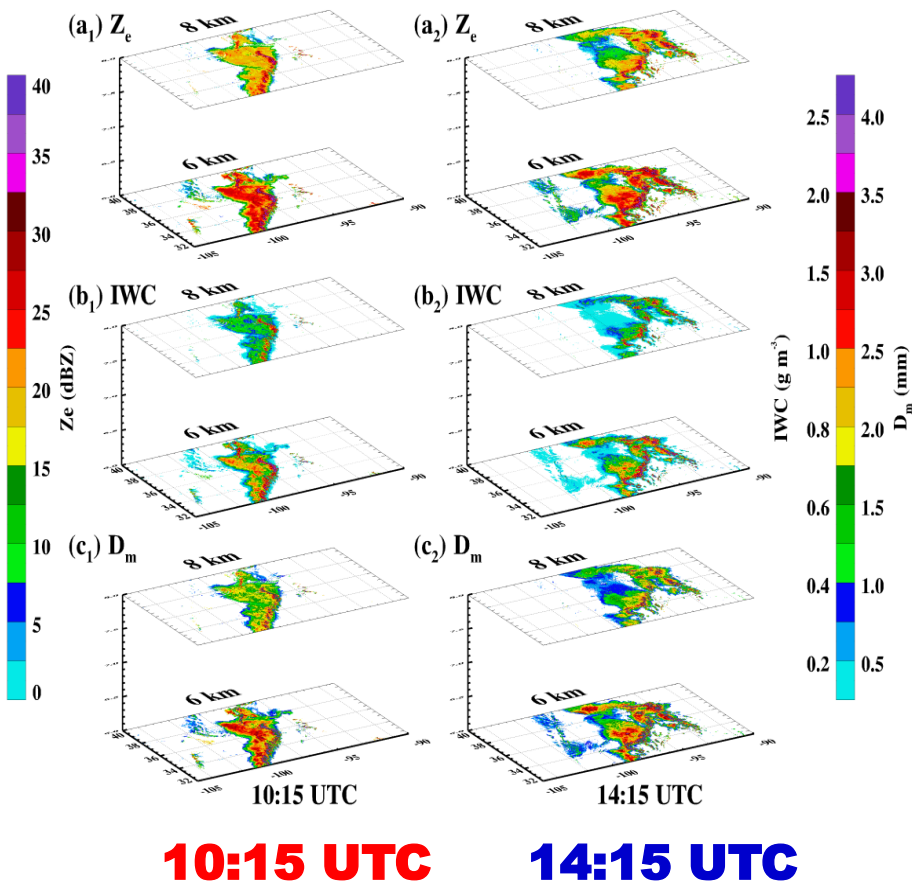
- **For the previous studies, we used ARM ground-based and point observations/retrievals to evaluate CERES-MODIS stratus cloud retrievals, such as ARM temporal averages vs. MODIS spatial averages.**

- **With the recently developed 4D cloud property retrievals using NEXRAD radar reflectivity (Tian et al. 2015) and validated by aircraft in situ measurements (Wang et al. 2015), we can validate the CERES-MODIS and GOES retrieved ice cloud microphysical properties (upper layers) of DCSs, and extend our validation study from the ARM SGP site to continental USA.**

- **This study will focus on the DCS cases selected during MC3E because Aircraft in situ data are available.**

Introduction of new Retrievals (Tian et al. 2015)





10:15 UTC **14:15 UTC**

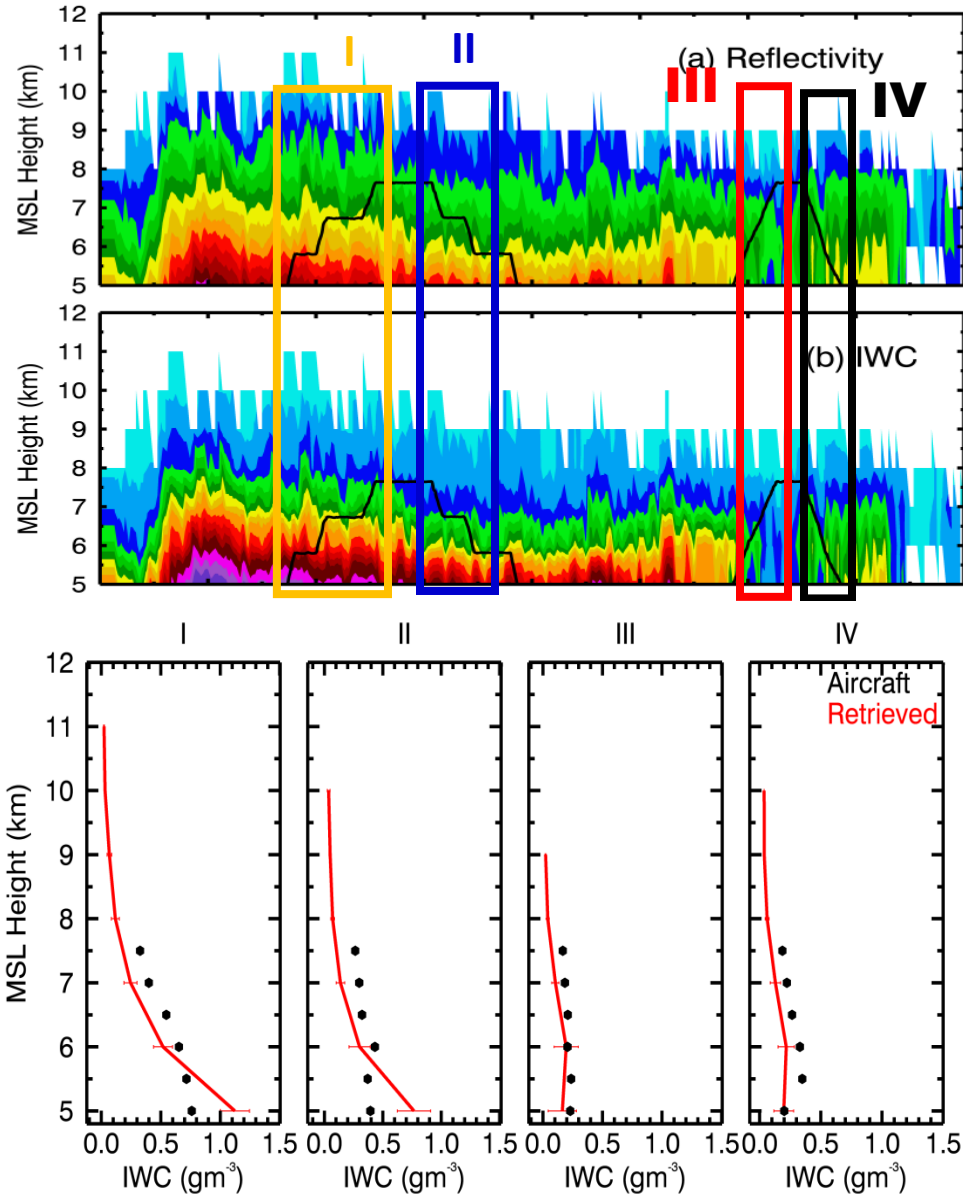
Based on NEXRAD 3D reflectivity, we developed a new method to retrieve 3D ice water content (IWC) and medium diameter (D_m) of DCSs

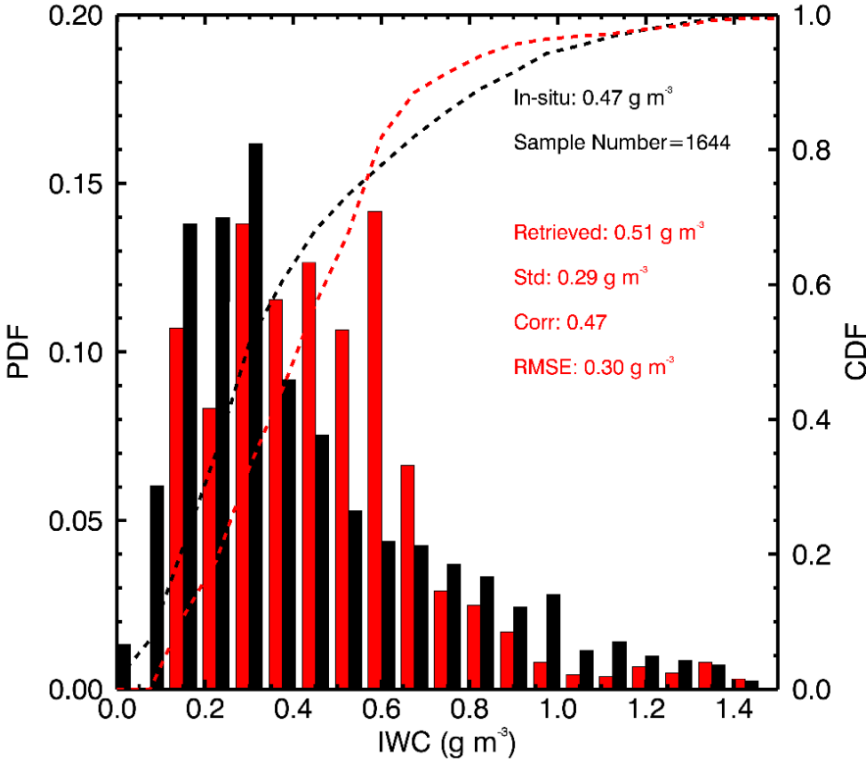
(a) Left: NEXRAD Reflectivity Profile; Right: Reflectivity distribution at 6 and 8 km

(b) Left: IWC profiles; Right: IWC areal distribution at 6 and 8 km

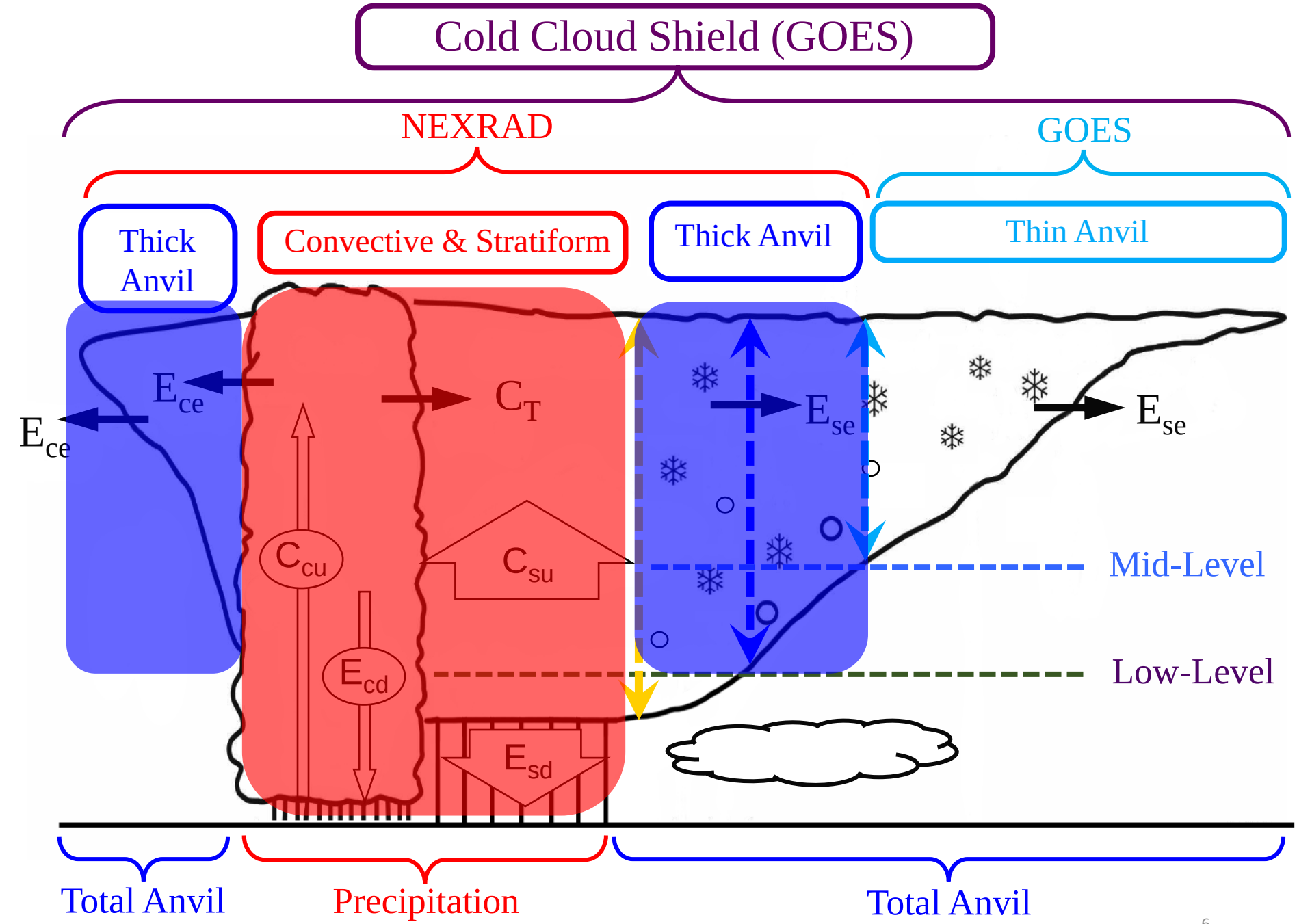
(c) Left: D_m Profiles; Right: D_m areal distribution at 6 and 8 km

Validating NEXRAD IWC retrievals using aircraft in situ data (Tian et al. 2015; Wang et al. 2015)





In addition to four profile comparisons, we also have statistical comparisons during MC3E (1644 samples). The mean difference between our retrieval and in-situ data is less than 9% with a correlation of 0.47, and an RMSE of 0.30 g/m^3.



Feng et al. (2011) JGR

Data and Methodology

Ground-based

IWC **and** D_e **vertical profiles every 15 minutes centered at CM overpasses in a grid box of 30X30 km² within 90 °W to 105 °W and 32 °N to 40 °N domain.**

$$IWP = \int_{5\ km}^{ctop} IWC\ dZ$$

$$D_e = \frac{\int_{5\ km}^{ctop} D_e\ dZ}{f(z)}$$

GOES

IWP **and** D_e **values every ~30 minutes centered at CM overpasses in a grid box of 30X30 km² within 90 °W to 105 °W and 32 °N to 40 °N domain.**

D_e **retrieved at 3.7 um**

IWP$= f(D_e , \tau_{vis})$

CERES-MODIS

IWP and De **are averaged SSF within a grid box of 30x30 km² in the same domain as ground-based and GOES data.**

D_e **retrieved at 3.7 um**

IWP$= f(D_e , \tau_{vis})$

Criteria for selecting DCS samples

1) From Surface NEXRAD view:

Only Stratiform Rain (SR), Convective Core (CC) and Thick Anvil (AC_{thick}) regions were selected from UND classification algorithm

2) From Satellite view:

Z_{top} > 8km, optical depth > 30, and Z_{base} < 4km

Daytime overpasses with SZA ≤77°

Objective:

Ice water path (IWP) comparison between NEXRAD and CM-MODIS/GOES retrievals during MC3E.

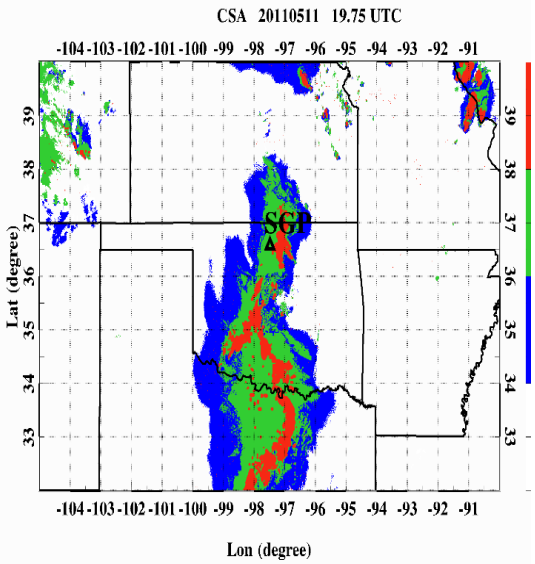
Assumption:

The phase identified by 3.7 um must be consistent with the ground-based measurements, that is, the ice can be only existed above melting band.

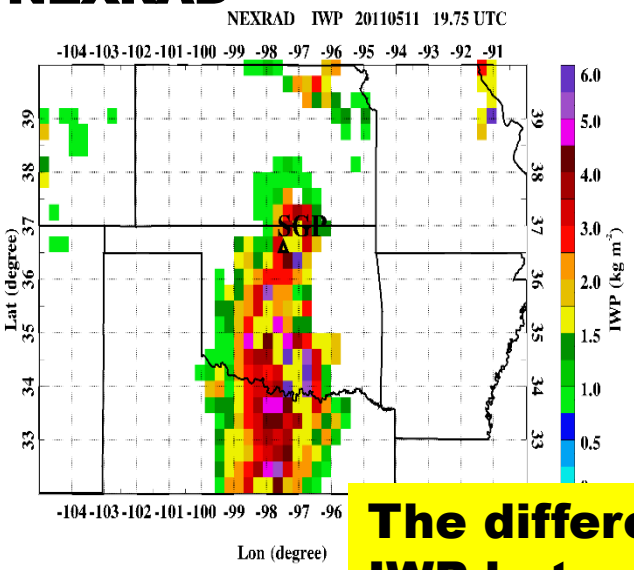
In this study, we average all NEXRAD retrieved ice cloud properties above 5 km of DCSs to compare with satellite retrievals.

Results: IWP 05/11/2011 19:45 UTC

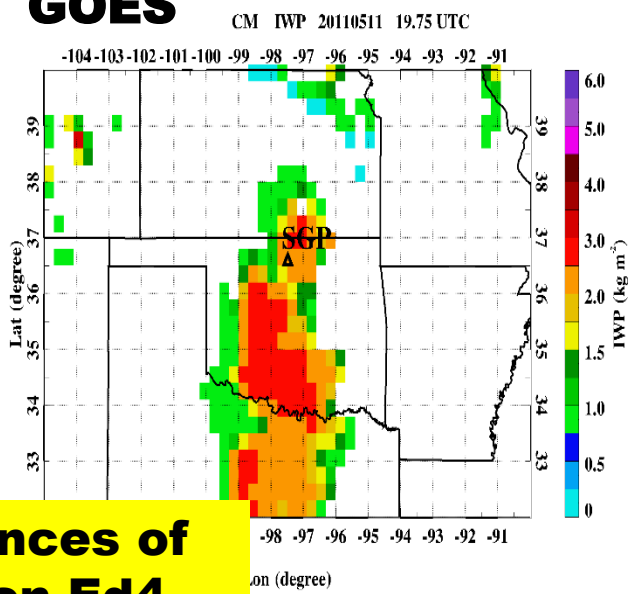
Classification



NEXRAD

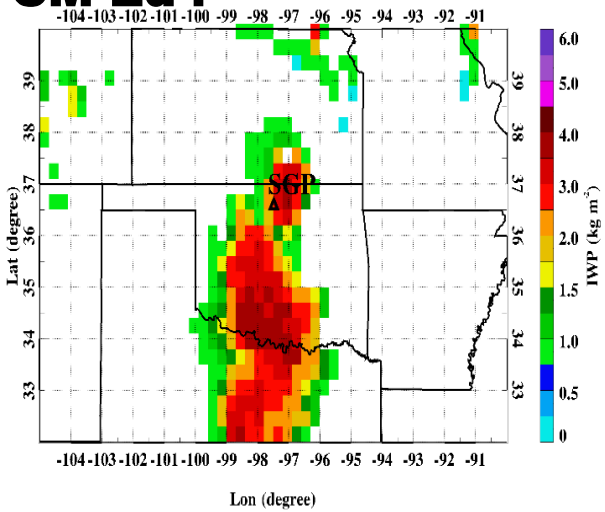


GOES

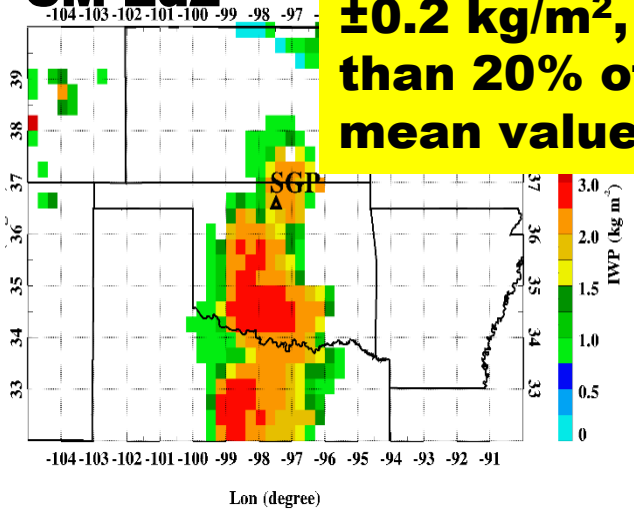


The differences of IWP between Ed4 and Ed2 are within ±0.2 kg/m², less than 20% of their mean values

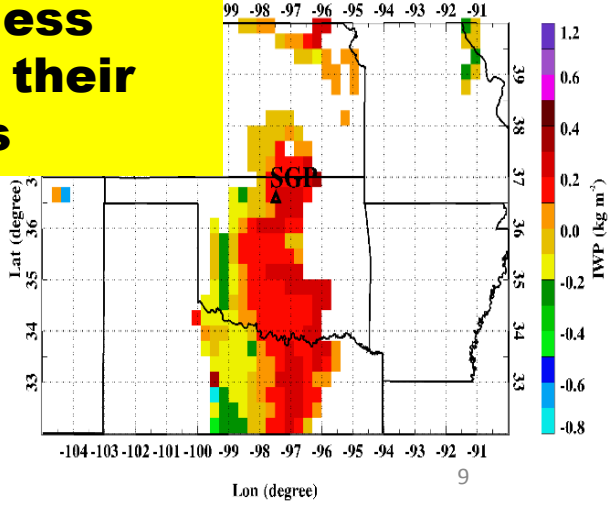
Aqua CM Ed4



Aqua CM Ed2

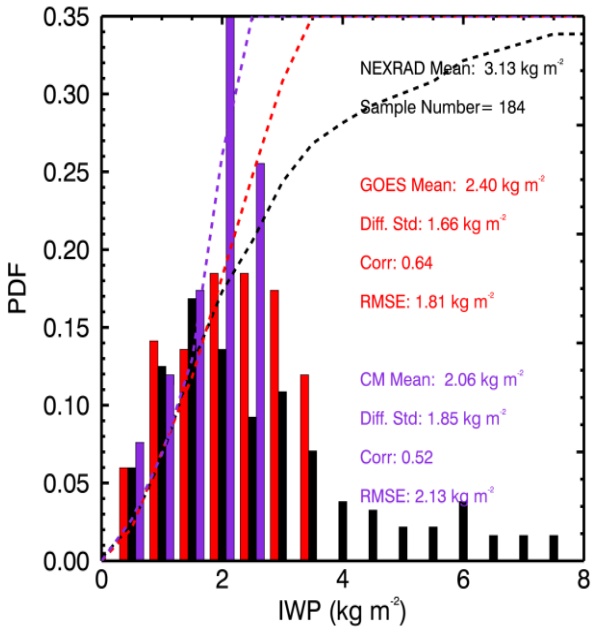


Ed4 – Ed2

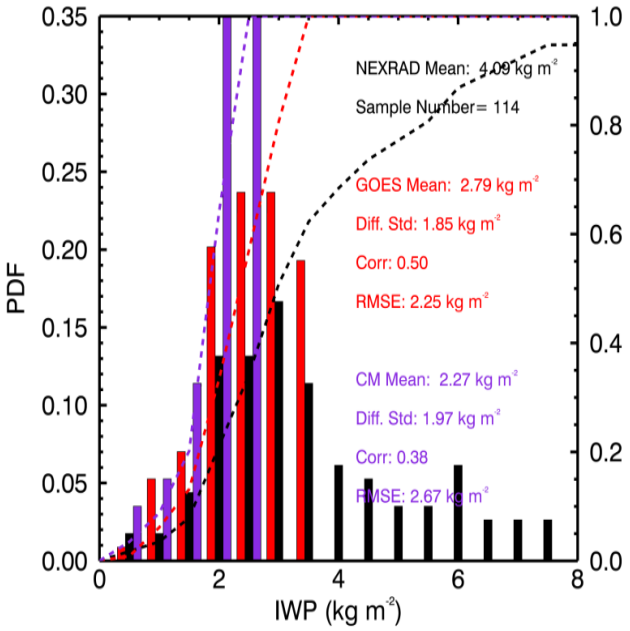


IWP Comparisons: 05/11/2011 19:45 UTC

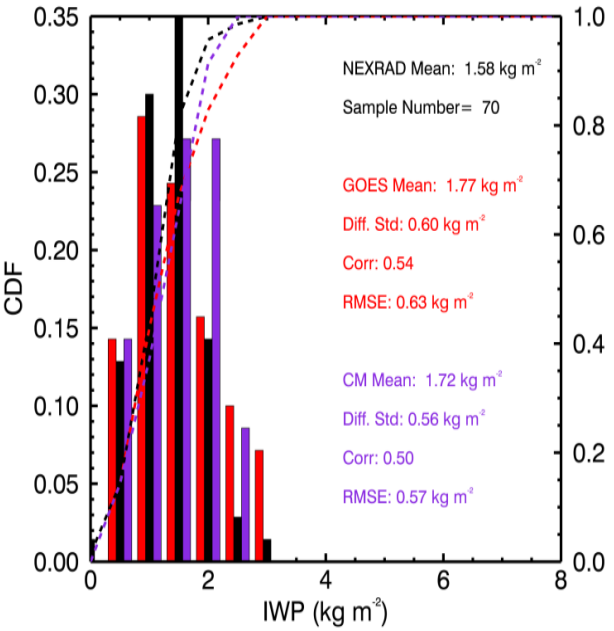
All Samples



CC & SR samples



Thick Anvil Samples



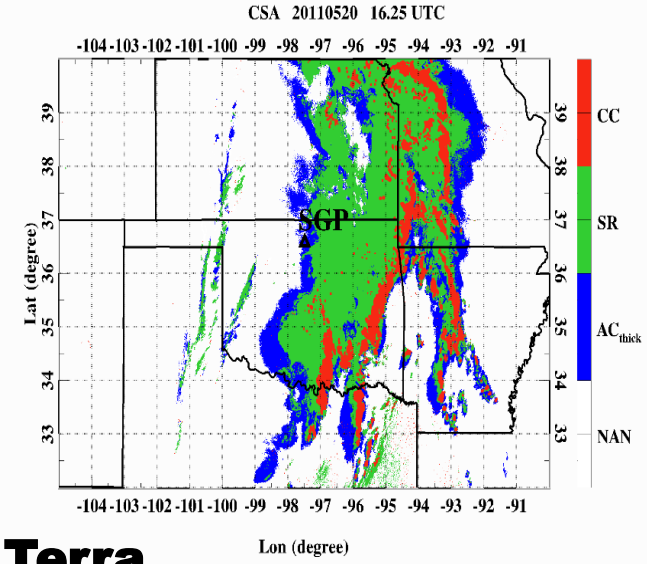
	ALL	CC+SR	Thick Anvil
Samples	184	114	70
CM-NEXRAD	2.06 - 3.13 = -1.07 kg/m², or - 34%	2.27 – 4.09 = -1.82 kg/m², or - 44%	1.72 – 1.58 = + 0.14 kg/m², or + 9%
GOES-NEXRAD	2.4 - 3.13 = -0.73 kg/m², or - 23%	2.79 – 4.09 = -1.3 kg/m², or - 32%	1.77 – 1.58 = + 0.19 kg/m², or + 12%

1) All IWP retrievals are much higher in CC&SR than in thick Anvil

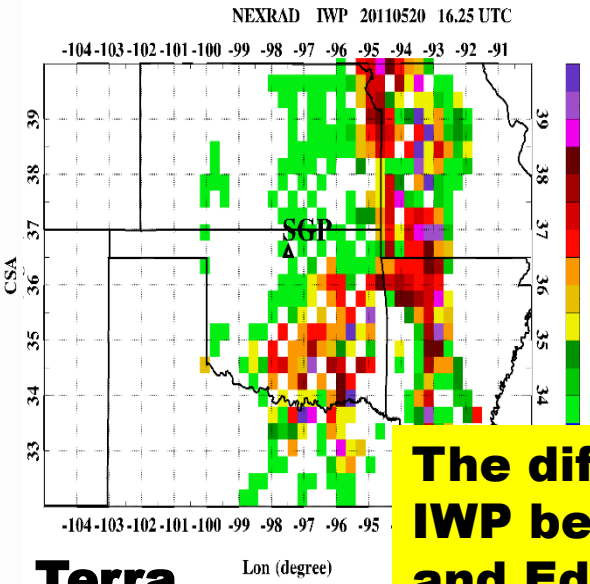
2) CM and GOES retrievals are severely underestimated by 32-44% in CC and SR regions, but overestimated by 10% in thick Anvil region.

Results: IWP 05/20/2011 16:15 UTC

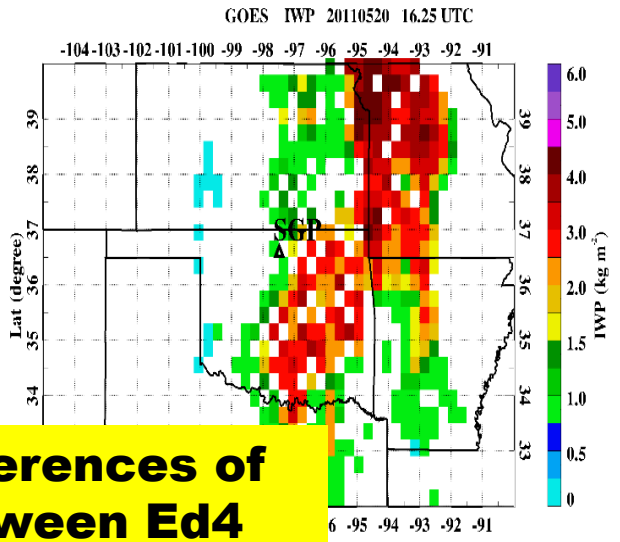
Classification



NEXRAD

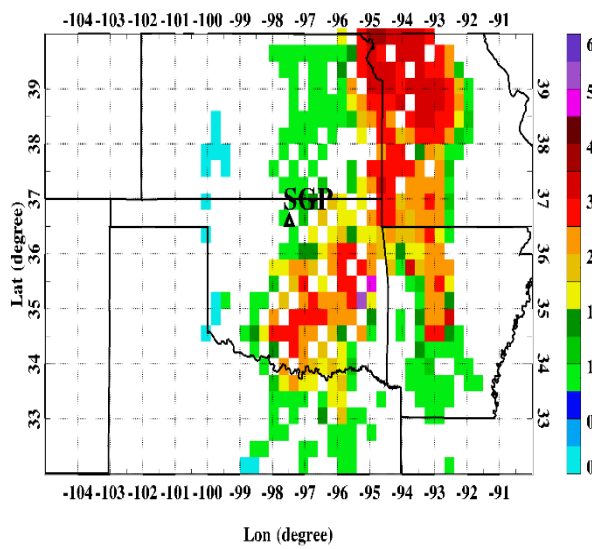


GOES

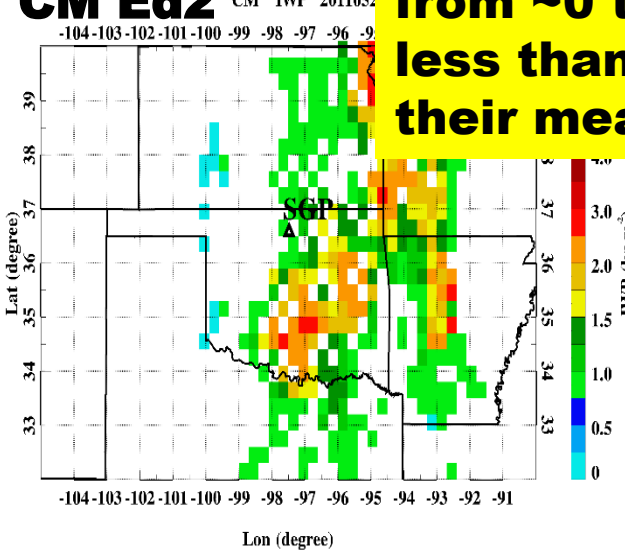


The differences of IWP between Ed4 and Ed2 ranges from ~0 to 1.2 g/m², less than 30% of their mean values

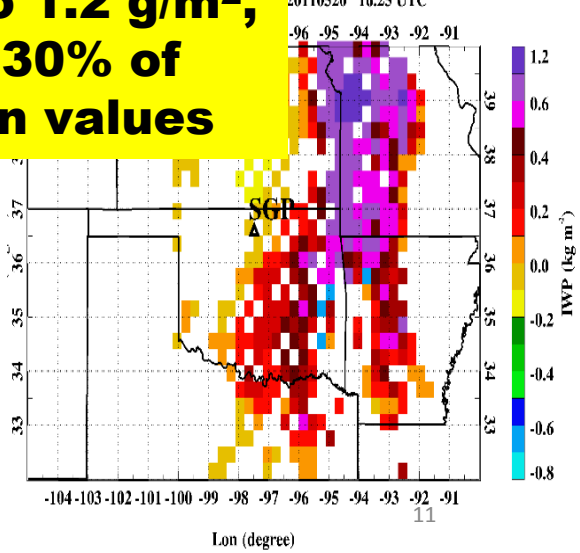
Terra CM Ed4



Terra CM Ed2

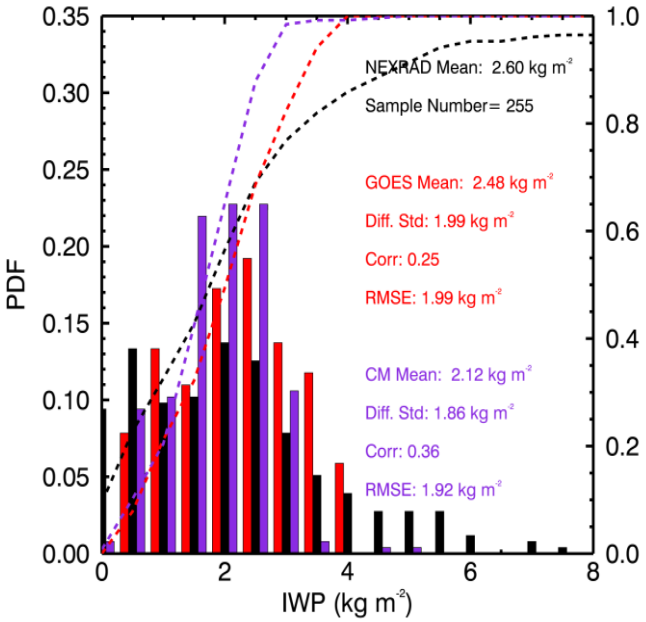


d4 – Ed2

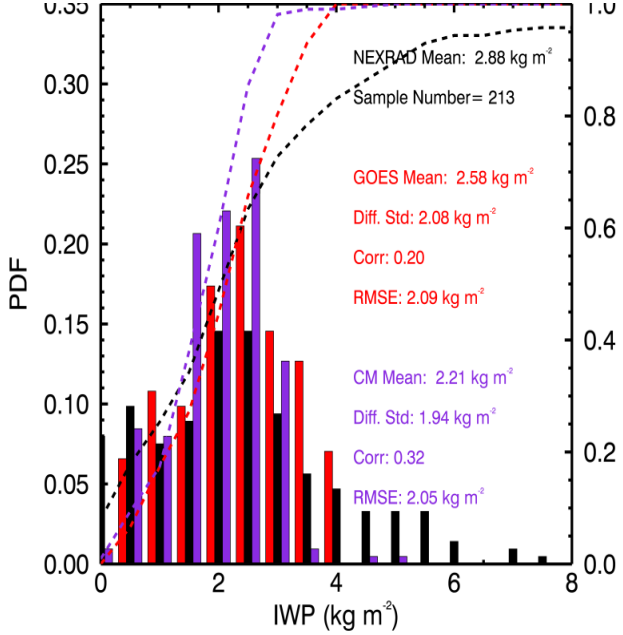


IWP Comparisons: 05/20/2011 16:15 UTC

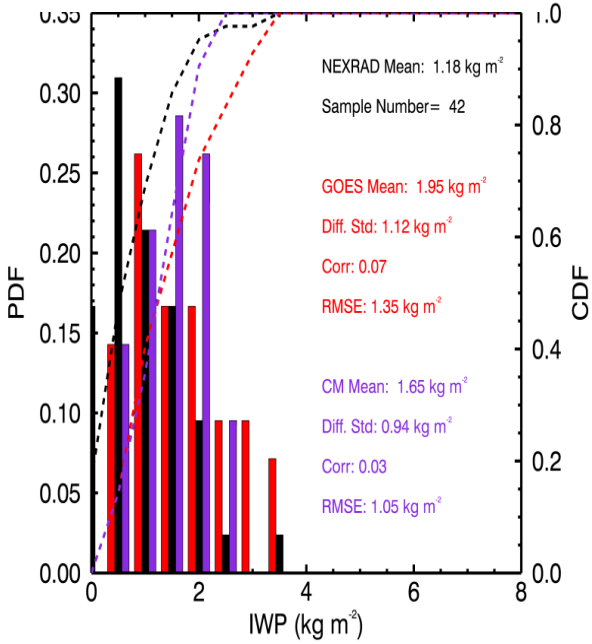
All Samples



CC & SR samples



Thick Anvil Samples

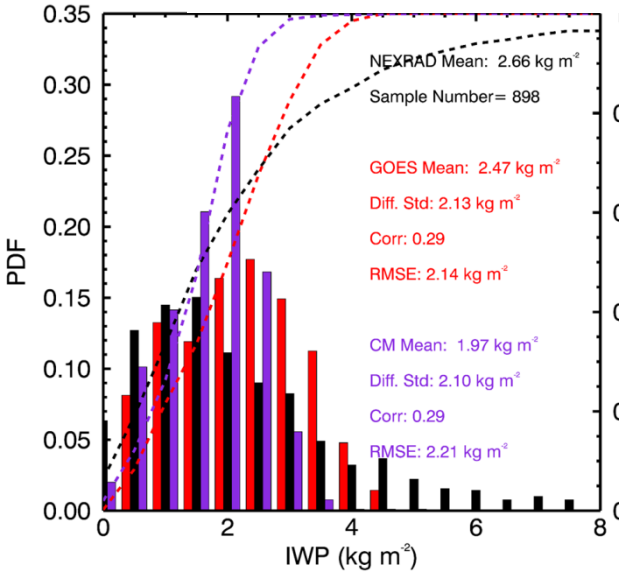


	All	CC+SR	Thick Anvil
Samples	255	213	42
CM-NEXRAD	2.12 – 2.6 = - 0.48 kg/m², or - 18%	2.21 – 2.88 = - 0.67 kg/m², or - 23%	1.65 – 1.18 = + 0.47 kg/m², or + 40%
GOES-NEXRAD	2.48 – 2.6 = - 0.12 kg/m², or - 4%	2.58 – 2.88 = - 0.3 kg/m², or - 10%	1.95 – 1.18 = + 0.77 kg/m², or + 65%

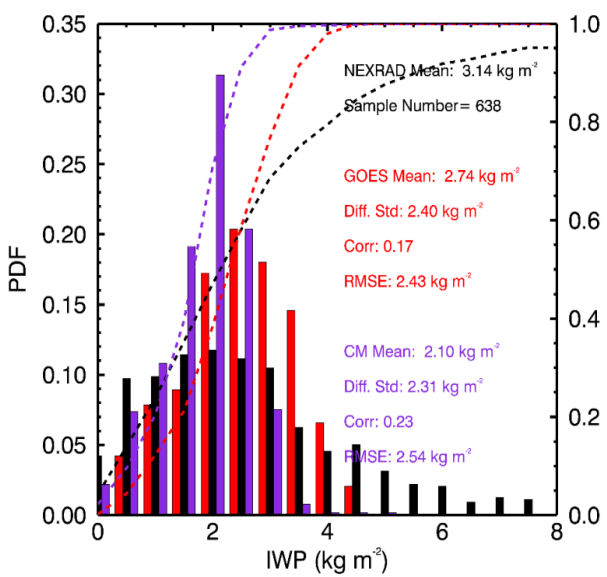
CM and GOES retrievals are overestimated by 40-65% in Anvil region.

Statistical IWP Comparisons: All cases

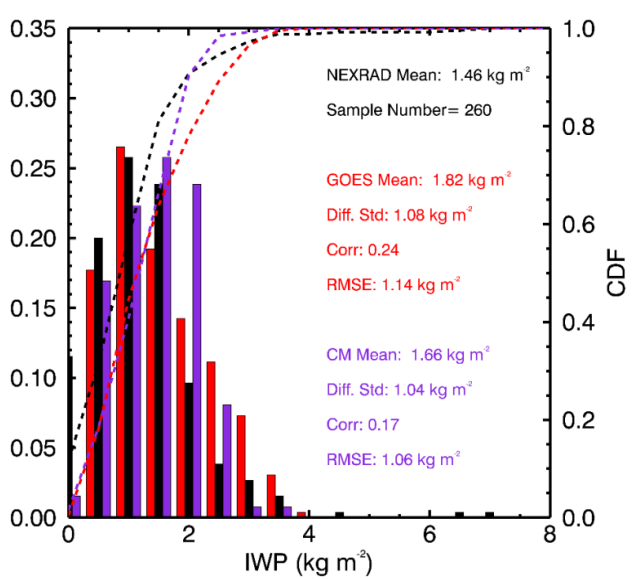
All Samples



CC & SR samples



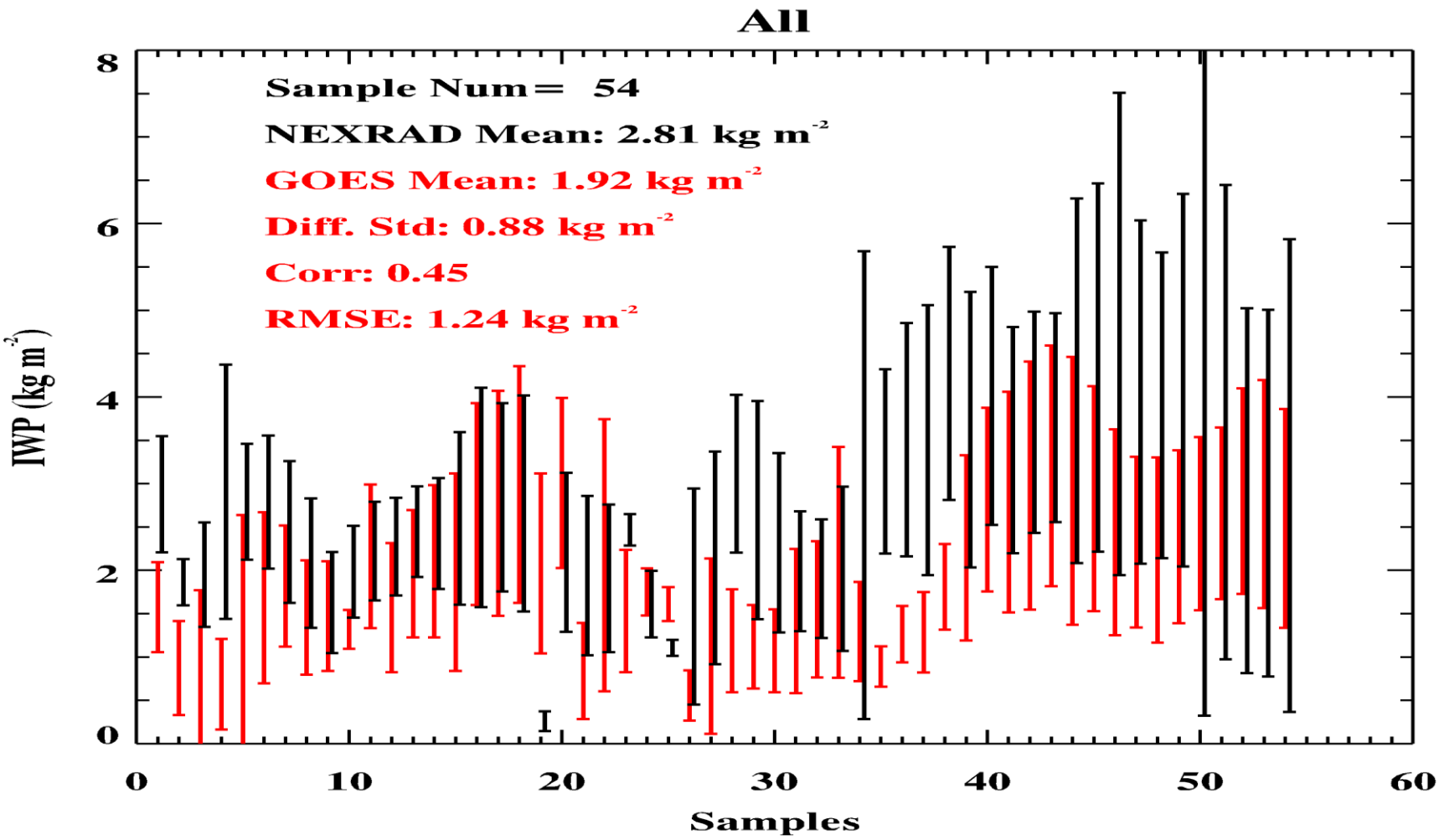
Thick Anvil Samples



	All	CC+SR	Thick Anvil
Samples	898	638	260
CM-NEXRAD	1.97 – 2.66 = - 0.69 kg/m², or - 26%	2.1 – 3.14 = - 1.04 kg/m², or - 33%	1.66 – 1.46 = + 0.2 kg/m², or + 14%
GOES-NEXRAD	2.47 – 2.66 = - 0.19 kg/m², or - 7%	2.74 – 3.14 = - 0.4 kg/m², or - 12%	1.82 – 1.46 = + 0.36 kg/m², or + 25%

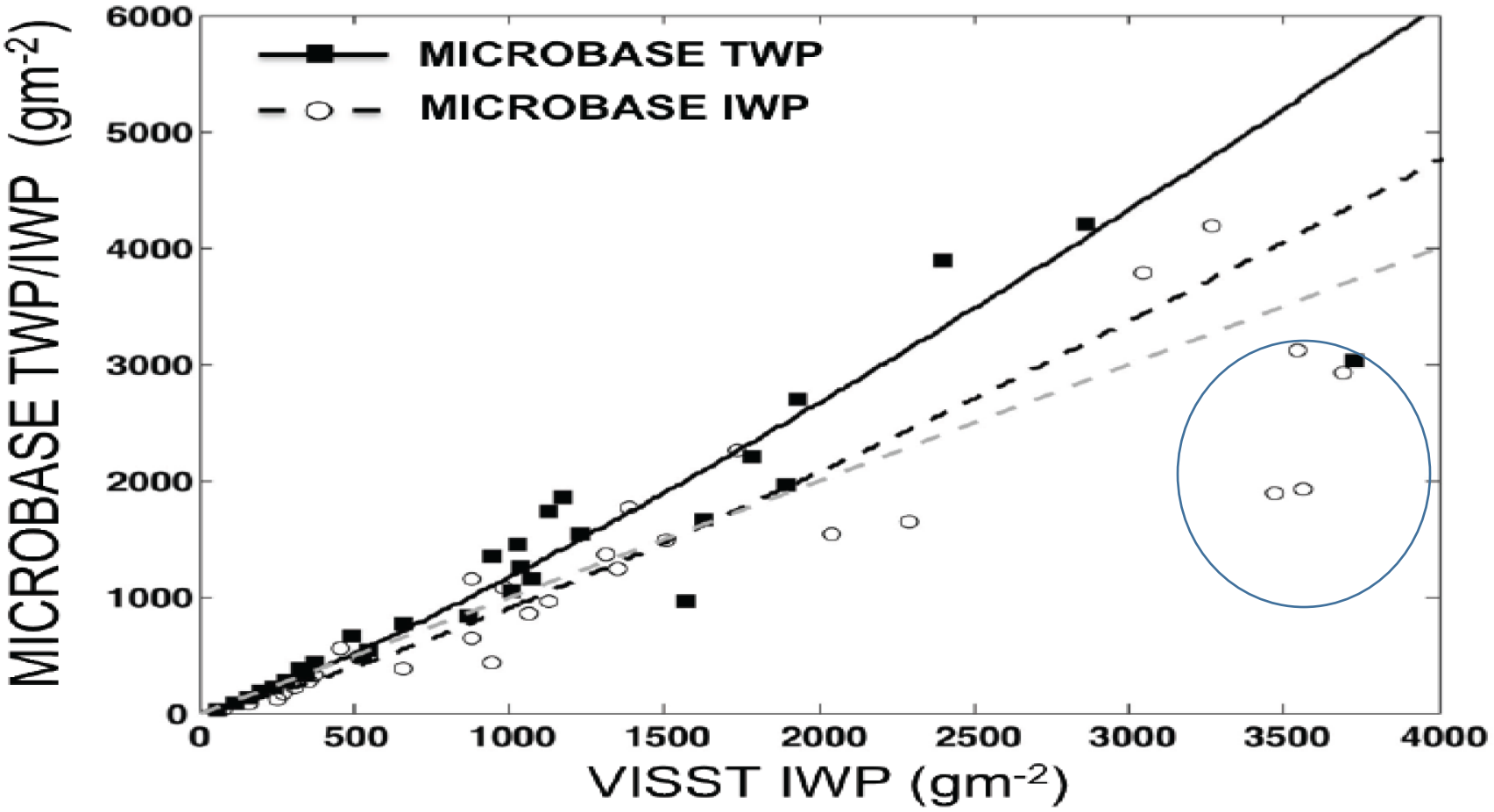
1) IWP values in CC+SR regions are much higher than those in Anvil region.
2) Both CM and GOES IWPs agree well with NEXRAD retrievals in Anvil region, but severely underestimate in CC&SR regions.
3) GOES IWPs are slightly better than CM retrievals.

Temporal Comparisons between NEXRAD and GOES (Daytime only)



Based on 54 temporal averages, the GOES retrieved IWP (= 1.92 kg/m^2) is 32% lower than NEXRAD IWP (= 2.81 kg/m^2) with a correlation coefficient of 0.45.

Comparison of IWP and TWP between GOES and ARM MICROBASE retrievals [Smith]



ARM MICROBASE retrievals are primarily from cirrus and anvil clouds, not from DCS clouds. Therefore, their retrievals are lower than GOES retrievals, especially for optically thick clouds (larger IWP values).

IWP Comparisons between CERES-MODIS, Cloudsat/CALIPSO, MODIS-IWP253 [Smith]

Table 4b. Similar to Table 4a but showing the mean values of IWP (gm^{-2}) retrieved and computed above the -20°C altitude level (IWP253). Hybrid0 is the MODIS IWP253 computed without employing the TWP parameterization. For context, the traditional full column MODIS IWP and the parameterized TWP derived from MODIS are also shown.

COD	N	Mean COD	MODIS IWP	MODIS TWP	CC-IWP253	MODIS-IWP253		
					C3M	RUC	Hybrid	Hybrid0
10-20	5083	14	310	405	191	157	169	132
20-40	4149	28	592	849	333	302	324	228
40-80	2635	54	1132	1754	668	718	767	486
80-150	730	106	2239	3815	1231	1522	1507	868
150	965	150	3006	5437	2549	2608	2688	1409
10-150	13562	41	860	1342	551	557	583	364

1) **IWPs increase with COD because IWP~ COD*De**
2) **CERES-MODIS retrieved IWPs are higher than Cloudsat and MODIS-IWP253 retrievals, and the differences increase with increased COD.**

How do these comparisons relate to this study?

1) Anvil region:

We found the CM and GOES IWP retrievals agree well with NEXRAD retrievals, consistent to their comparisons with ARM MICROBASE, Cloudsat, and MODIS-IWP253 retrievals.

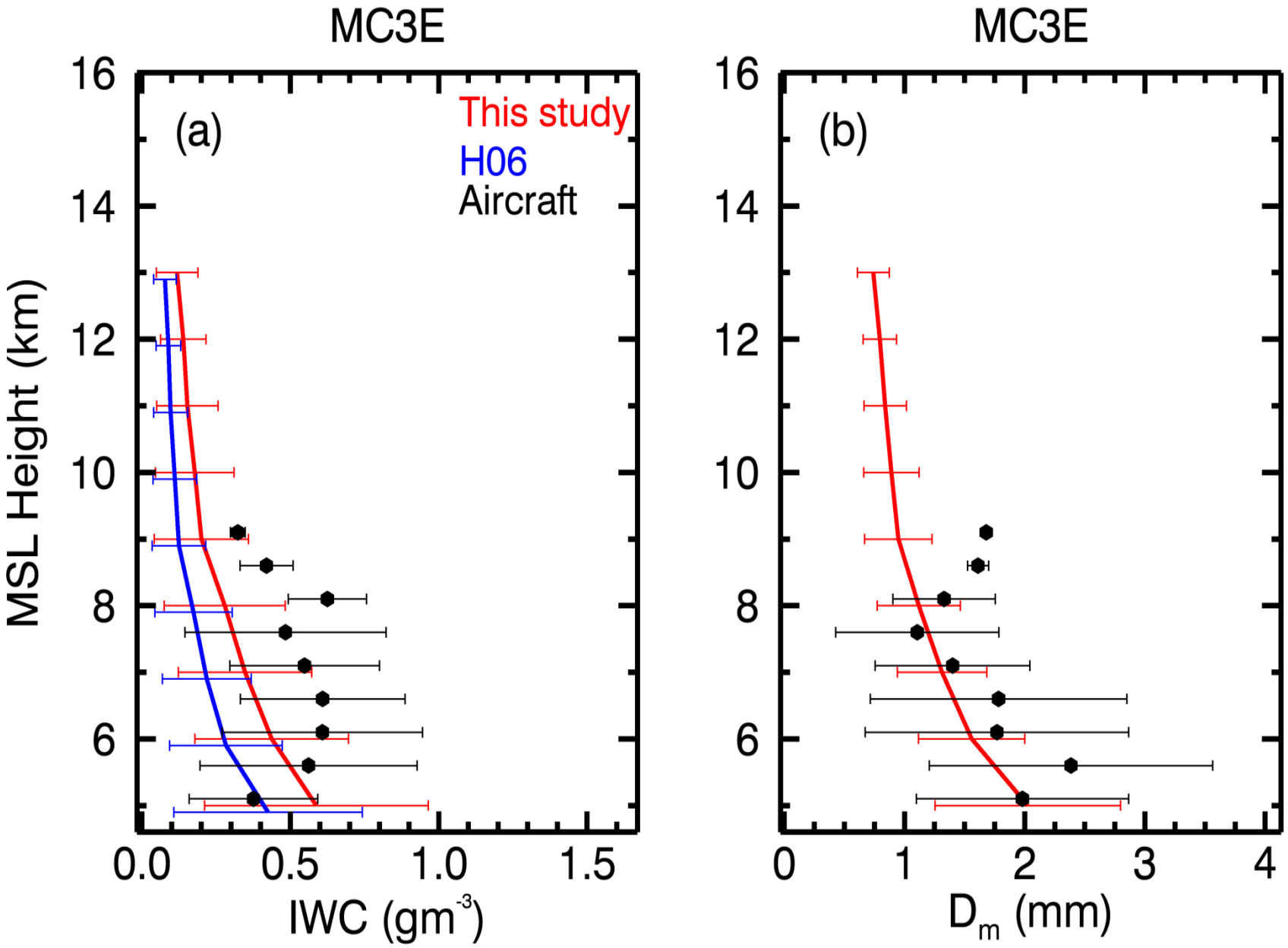
2) CC&SR regions (large COD and IWP values):

We found the CM and GOES IWP retrievals are much less than NEXRAD retrievals, opposite to their comparisons with others. Which one is right and which direction for CM and GOES retrievals should go?

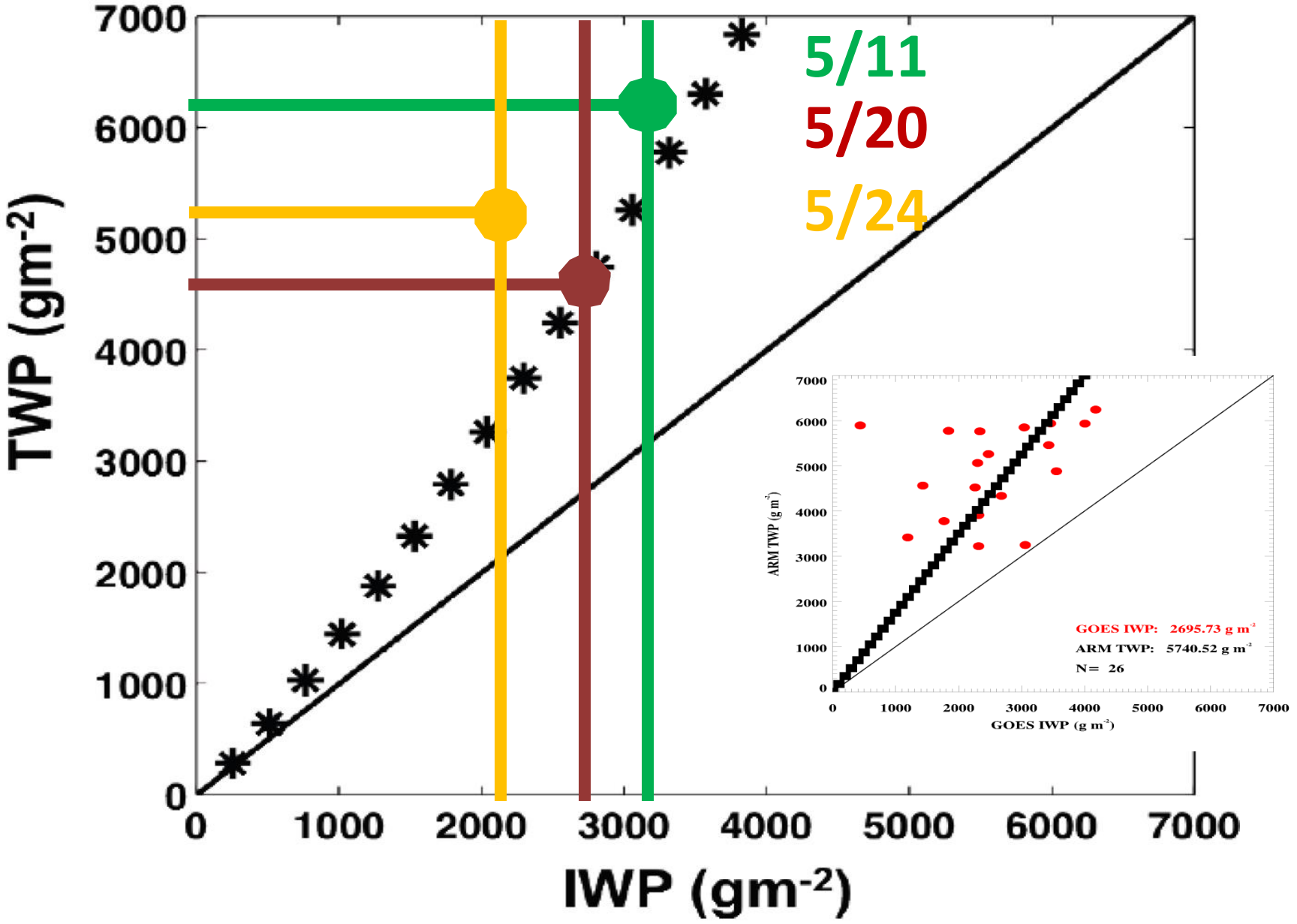
3) Discussion for the discrepancies over CC&SR regions:

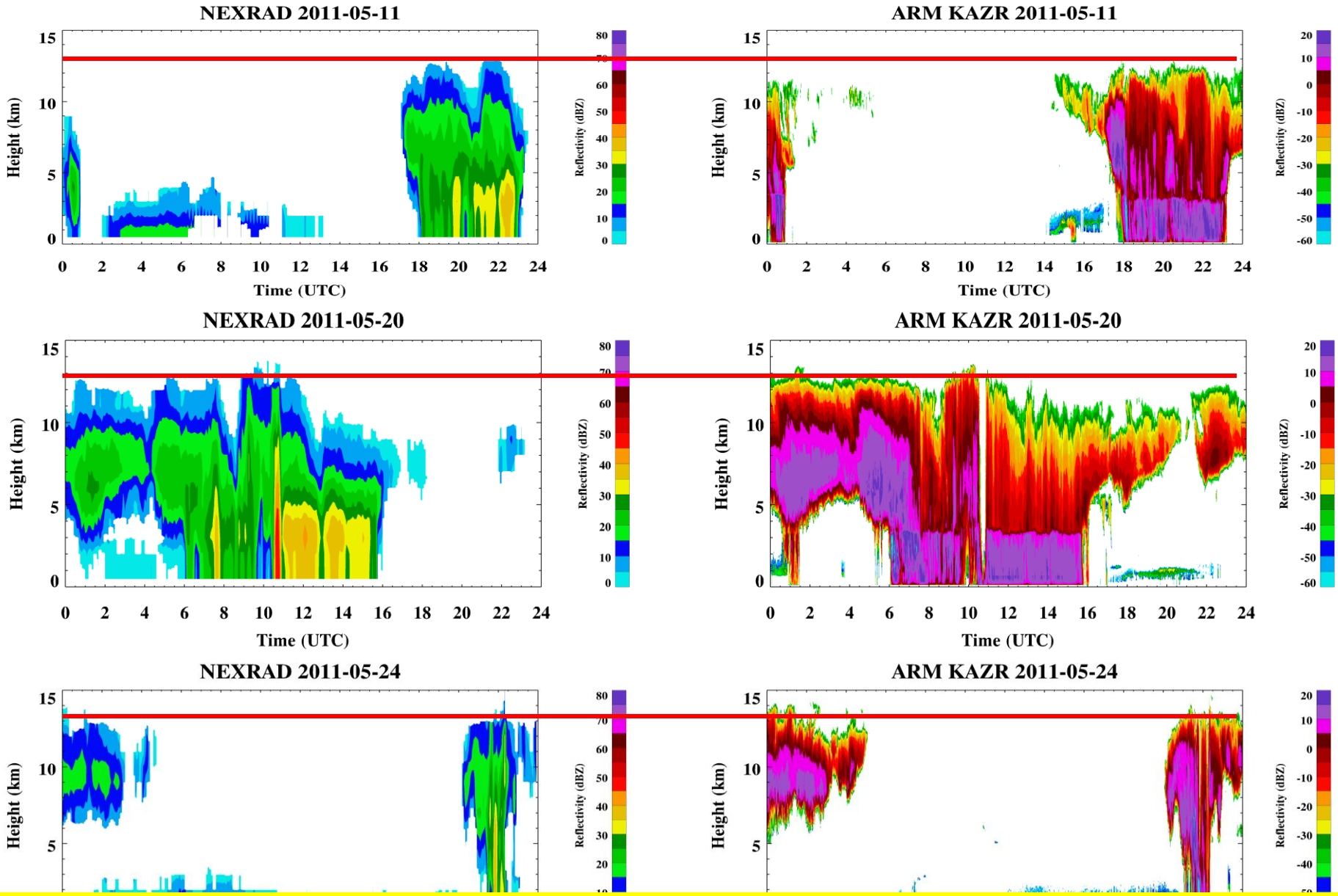
- **IWP ~ COD*De. For visible channel, it may penetrate entire cloud layer, so the CM and GOES COD values may represent entire cloud layer information. However, their De retrievals are based 3.7/3.9 μm channel, which represents the upper levels of clouds.**
- **As we know, De increases from top to bottom of DCS as shown in our retrievals and aircraft data. Therefore, it is highly possible for CM and GOES to underestimate IWPs.**

IWC and De increase from top to bottom in DCS



TWP~ 2*IWP based on ARM TWP and GOES IWP





NEXRAD can measure the same cloud top as KAZR, even higher without attenuation for DCS. KAZR measurements were severely attenuated (20 dB less than NEXRAD), particular heavy rain events.

Summary

IWP Comparison

1) IWPs in CC+SR regions are much higher than those in Anvil region.
2) Both CM and GOES IWPs agree well with NEXRAD retrievals in Anvil region, but severely underestimate in CC+SR regions.
3) GOES IWPs agree with NEXRAD retrievals better than CM retrievals.

For temporal comparisons between GOES and NEXRAD

Based on 54 temporal averages, the GOES retrieved IWP (= 1.92 kg/m^2) is 32% lower than NEXRAD IWP (= 2.81 kg/m^2) with a correlation coefficient of 0.45.

The mean D_e values from NEXRAD and GOES retrievals are very close, but with large variation for some samples.

TWP vs. IWP for DCS

TWP~ 2*IWP based on ARM TWP and GOES IWP, consistent to Smith's parameterization.